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Ultrasonic Filtration of Combined Sewer Overflows

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ULTRASONIC FILTRATION OF COMBINED SEWER OVERFLOWS

EPA Program
11023 DZF 06/70

American Process Equipment Corporation, Hawthorne, California

~~14-12-195~~

Environmental Protection Agency, ~~Water Quality Office~~, Water Pollution Control Research Series ~~No. 11023, DZF~~, June 1970, 49 p., 13 fig.

Simulated combined sewer overflows and primary treatment plant effluent were used to test a 250,000 gpd compact ultrasonically cleaned microfiltration system composed of twenty porous polyethylene elements of 0.8 sq. ft. area each. Study indicates that the use of more costly porous stainless steel elements would alleviate the clogging of filters. Filter clogging at the Atlanta, Georgia test site prevented showing the feasibility of treating combined sewer overflows. In more suitable water pollution control applications, it is possible to reduce BOD and suspended solids in raw settled sewage, or effluents from primary and secondary plants by 50%, using ultrasonic filtration and having initial levels of influent BOD and suspended solids of 100 mg/l or less. A vortex separator was designed as a pretreatment device for the filter. (Smith-Texas)

*Suspended solids, *Biochemical oxygen demand, *Filtration, Ultrasonics, Sewage, Water pollution, *Waste water treatment

*Ultrasonic filtration, *Combined sewer overflows, Vortex separator, Polyethylene

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Ultrasonic Filtration of Combined Sewer Overflows

by

American Process Equipment Corporation
3309 West El Segundo Boulevard
Hawthorne, California 90250

for the

ENVIRONMENTAL PROTECTION AGENCY

WATER QUALITY OFFICE

Program Number - 11023DZF
Contract Number 14-12-195

June, 1970

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ABSTRACT

A 250,000 gpd compact ultrasonically cleaned microfiltration system was tested with simulated combined sewer overflows and primary treatment plant effluent. Twenty 35 micron porous polyethylene elements of 0.8 sq ft area each comprised the system.

Simulated settled combined sewer overflows at Atlanta, Georgia test site quickly clogged filters with high concentrations of rust in both influent and fresh backwash water. Thus, feasibility of treating combined sewer overflows was not demonstrated. Study indicates use of more costly porous stainless steel elements would obviate this problem.

Sufficient test data are available to predict performance in more suitable water pollution control applications. With influent BOD and suspended solids levels of 100 mg/l, or less, ultrasonic filtration using 35 micron plastic elements can reduce BOD and SS in raw settled sewage, or effluents from primary and secondary plants by 50%. A 25 MGD system requires less than 20,000 square feet, and cost for treating 1,000 gallons is $0.08, excluding pretreatment.

Contractor's novel flotation vortex separator reduced raw sewage BOD 45% and influent solids 80%. This "VORSEP" could continuously treat combined sewer overflows, and/or pretreat influent to the ultrasonic microfiltration system. A 25 MGD Vorsep treats 1,000 gallons for $0.03, and requires 10,000 sq ft of space.

This report is submitted in fulfillment of Contract 14-12-195 between the Environmental Protection Agency, Water Quality Office and American Process Equipment Corporation.

Key Words: Ultrasonic Filtration
Combined Sewer Overflows
Vortex Separator

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SECTION 1

CONCLUSIONS

1. Filtration of settled combined sewage or simulated combined sewer overflows at a test site in Atlanta, Georgia, was unsuccessful. The cause of failure was identified as excessive, irreversible filter clogging by rust particles introduced in part by corrosion in the pretreatment tanks and piping and in part from the fresh water supply used for backwashing. It has subsequently been determined that the clogging problem was aggravated by the use of inexpensive porous polyethylene filter elements having an unusually large affinity for rust particles as compared to much more costly porous sintered stainless steel elements.

2. Effective continuous filtration required waste water pretreatment by settling or other means to provide an influent with no more than 100 ppm of suspended solids and BOD.

3. At the Atlanta test site, a particle size distribution analysis conducted by the Georgia Tech Research Institute showed that suspended solids remaining after pretreatment were primarily unicellular bacteria of less than 5 microns diameter. To capture these smaller particles would have necessitated use of finer-pored filter elements having a reduced flow efficiency.

4. The semi-automatic microfiltration system is best suited for application to an influent of relatively uniform quality day-by-day.

5. Inexpensive, porous polyethylene filter elements were demonstrated to be functional in rust-free applications as permanent, recleanable filter media, and are preferred to more expensive sintered porous stainless steel elements initially evaluated.

6. The semi-automatic microfiltration system was successfully operated to meet completely its designed operating parameters: Total flow rate of 250,000 gpd; automatically controlled periodic pressurized backwash; automatically controlled periodic *in situ* application of ultrasonic energy to enhance cleaning of filter elements during backwash; and filtration efficiencies with 35 micron porous filter elements as high as 15 gpm/sq ft.

7. The filtration system (above) removed up to 50% of BOD and suspended solids from a domestic sewage primary treatment effluent.

8. A novel vortex separator recently developed by the Contractor and tested in prototype form both with raw sewage and mixed liquors obtained after secondary treatment shows substantial promise in future full-scale installations as a continuous sedimentation device capable of providing effective pretreatment of high volume combined sewer overflows.

SECTION 2

RECOMMENDATIONS

1. The Atlanta test site, with its installed availability of pumps, power, tanks, and other auxiliary equipment, should be utilized for further study of combined sewer overflow pre-treatment processes with the vortex-type flotation system.

2. The trailer-mounted microfiltration system should be refurbished to eliminate sources of filter-plugging rust and to eliminate excessive maintenance of certain unreliable automatic valves controlling forward and backwash flows by substituting more reliable equivalents. The system should be refitted with stainless steel elements in applications where rust may be encountered.

3. The refurbished microfiltration system should be further evaluated for its efficacy in removing pollutants from selected waste waters; e.g., secondary effluents, industrial wastes with fibrous or non-colloidal particulate contaminants, or chemically flocculated wastes.

4. Waste waters should first be analyzed for suspended solids, per cent dissolved BOD, etc., to determine the applicability for utilizing this treatment process.

SECTION 3

INTRODUCTION

This project was authorized to provide for the design, fabrication, and evaluation of a semi-automatic ultrasonic microfiltration system, of nominal 250,000 gpd capacity, for field use in treating combined sewer overflows. The field site was to be completely equipped with the ultrasonic microfiltration unit, a pretreatment unit, and all auxiliary equipment necessary for a complete demonstration of the facility.

The Contractor's test program was divided into two phases:

PHASE I - A test program utilizing a contractor-owned dual-canister laboratory scale ultrasonic filtration system to provide design data for the field unit.

PHASE II- Performance testing of the field unit at an FWQA-approved sewage treatment plant to develop operational procedures and evaluate system reliability. The field unit was subsequently to be moved to an FWQA-approved field site for performance testing with actual combined sewer overflows.

The semi-automated ultrasonic microfiltration system was selected for evaluation in treatment of combined sewer overflow discharges because of its potential in providing efficient removal of particulate pollutants from the large volumes of such waste waters encountered during periods of heavy rainfall. This potential is inherent in the system design, which features permanent, micro-porous filter elements, automatic forward and backwash flow controls, and *in situ* application of ultrasonic energy to enhance cleaning of the filter elements during periodic short or long backwash cycles. The system can provide filter efficiencies of 10-15 gpm/sq ft continuously, provided the influent has received requisite pretreatment. An explicit objective of the test program was to define "requisite pretreatment."

The dual-canister system had previously been evaluated in its earlier development stage with various influents, including raw sewage, under FWQA Contract No. 14-12-23 with Acoustica Associates, Inc., the company from which American Process Equipment Corporation evolved as an independent entity in March of 1968. During this previous program, the

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performance of a 7 gpm ultrasonic filtration system with 20 and 50 micron pore size stainless steel elements was evaluated with ordinary city water and with raw sewage variously diluted with city water to simulate combined sewer overflows. With 2 parts of water and one part of raw sewage passed through 50 micron elements, for example, reductions of 39% in BOD and 55% in suspended solids were realized. Similar results were obtained with other filter pore sizes and dilution ratios.

Based upon the results of the testing accomplished under Contract No. 14-12-23, the present program to more thoroughly evaluate the dual-canister system and expand upon its flow capabilities was initiated.

SECTION 4

DISCUSSION

PHASE I - Dual Canister Test Program

A. Laboratory-Scale Ultrasonic Filtration Unit

The Contractor-owned dual canister laboratory scale ultrasonic filtration system consisted of the following:

Two stainless steel canisters, each fitted with ASCO solenoid-operated valve influent port, effluent port, backwash port, drain port and air vent.

Canisters manifolded to permit either one or the other canister to maintain forward flow with *in situ* cleaning while the other is either undergoing a longer backwash cycle or is maintained idle in the clean condition.

Each canister containing a microporous filter element of either porous stainless steel or plastic. Of cylindrical construction, each element typically measured 10 inches long x 2.75 inches outer diameter and thus had an effective filtration surface area of 86 square inches or 0.6 square feet. Each element is sealed at the bottom and fitted at the top with a connection to the effluent and backwash manifold. Influent flow is into the canister, through to the interior of the filter element, and out the top fitting of the filter element to the manifold.

An electrostrictive ultrasonic transducer, driven by a 350 W output, 22 kHz ultrasonic generator, on the bottom plate of each canister. The transducer is activated during frequent, short cycles ("spritz") one second out of each 10 or 20 seconds, and during a long-clean backwash upon manual command or at any desired interval set by a cam timer system.

Dial pressure gauge on the inlet side of each canister.

An influent pump to the settling tank rated at 10 gpm flow at 30 psi.

A square box 20-mesh influent screen of stainless steel to remove gross objects, such as rags, sticks, etc.

A backwash pump rated at 15 gpm at 100 psi maximum.

Flow meters in the drain and backwash lines.

An electronic control box including stepping switches, cam timers and electronic timing circuits, manual override switches and indicator lights showing the operational status of the filters at any moment.

A 300-gallon capacity cylindrical steel settling tank used for pretreatment of raw sewage influents and a second influent pump for introducing settled sewage into the filtration system initially rated at 10 gpm flow at 30 psi and later doubled in flow capacity.

All of the foregoing system components were assembled for installation in the detritor building at the Hyperion Treatment Plant, of the City of Los Angeles, where sources of both raw sewage and effluent from a secondary plant were available conveniently. Figs. 1 and 2 show the equipment and the test setup comprising the Hyperion installation.

B. Test Program Objectives and Results

Objectives of the dual-canister test program involved hydraulic measurements of flow rate and head loss pressure; maximizing forward flow; optimizing pressure and application of backwash water; and determining the need, if any, for pretreatment processes, including screening, storage and flocculation, all determined with various types of porous filter elements. These tests were made with a variety of influents including settled and non-settled raw sewage variously diluted with fresh water and effluent from the secondary treatment plant at Hyperion.

(1) System Description

Before discussing detailed test results, a brief discussion of the operation of the ultrasonic filtration system itself will be presented. In this type of system using permanent-type elements, rapid plugging of the elements can be expected unless means for reducing and/or eliminating buildup of cake on the filters are incorporated. In early work with the Contractor-owned system employed to filter drinking water, periodic initiation of the "spritz" sequence was adequate to maintain each filter element in a "like-new" condition during forward flow. That spritz sequence involved the momentary stoppage of forward flow for 1 sec every 10 to 20 sec during which interval the drain to the canister

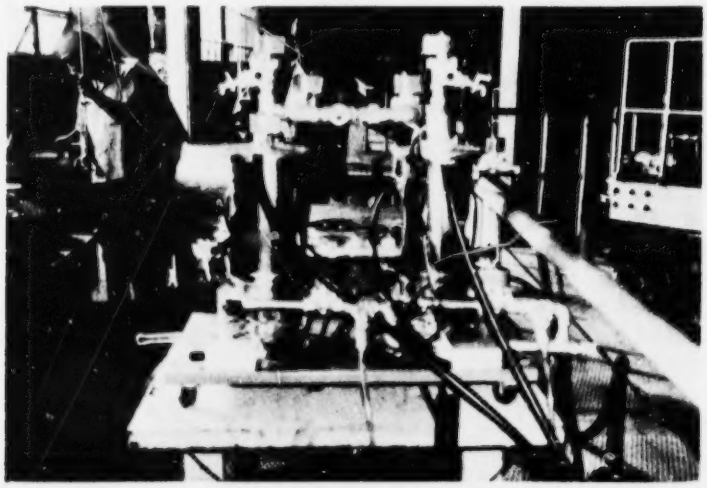


Fig. 1 - PHASE I DUAL-CANISTER SYSTEM

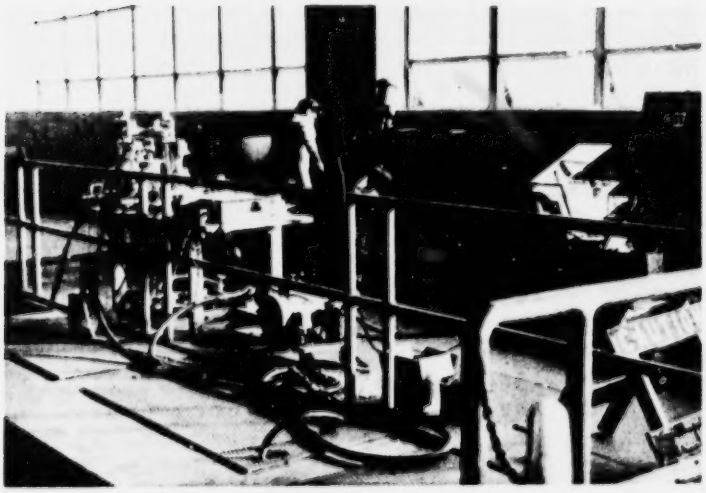


Fig. 2 - HYPERION TEST AREA

was opened simultaneous with the application of ultrasonic energy to the interior of the canister. Cake building up on the surface of the filter was dislodged and placed in suspension in the quiescent liquid surrounding the element, while a small portion of the influent within the canister was exhausted to the drain by gravity as the solenoid-operated air vent opened. Under light conditions of influent loading, typically 25 mg/l of mineral-type suspended solids and sand, the spritz renewed forward flow to the point where a periodic backwash of longer duration was needed only several times per day. Similar results were obtained when filtering various petroleum fuels.

In the Hyperion tests, however, it became evident shortly after tests commenced that because of the far heavier solids loadings encountered in settled raw sewage, the spritz must be augmented by adding a pressurized backwash during the short spritz sequence. The addition of pressurized spritz provided a very significant and substantial improvement in system operation and became standard in all further Phase I and Phase II work. With the addition of this pressurized spritz sequence aided by ultra-sound, all subsequent tests evaluating various filter elements and sequencing techniques were based upon maintaining the forward flow rate as close to constant as possible using pressurized spritz only, with the longer backwash being delayed in time as long as was feasible.

(2) Initial Phase I Tests

Initial tests during the Phase I effort involved the use of sintered porous stainless steel elements of 50 and 100 micron pore size. Such elements are commercially available in open cylinders and must be joined together by welding to fabricate elements of the 10 inches length used. Thereafter, end plates and the pipe fittings must be affixed. Ordinary welding techniques proved unsatisfactory, as the heat involved distorted the sintered bodies that cracked thereafter. This difficulty was rectified by substituting more expensive electron beam welding techniques.

Complete data obtained in each test at Hyperion are included in the Appendix. The sequence of hydraulic tests can be summarized in the order they were investigated as follows:

a. Non-pressurized spritz with stainless steel elements - premature clogging.

b. Pressurized backwash spritz with stainless steel elements - decided improvement.

c. Pressurized backwash spritz with Teflon elements - premature clogging.

d. Pressurized backwash spritz with polyethylene elements - superior performance.

Numerically, the hydraulic results for the best of the runs in each of the four categories listed above when conducted with settled raw sewage are shown in the following Table:

PARAMETER	CATEGORY			
	(a)	(b)	(c)	(d)
INFLUENT WATER DILUTION WATER/SEWAGE	10:1	1:1	1:1	1:1
FORWARD FLOW @ START,GPM	5.5	5.5	7.5	5.2
FORWARD EFFICIENCY @ START, GPM/SQ FT	9.4	9.4	12.5	8.7
FORWARD FLOW @ END, GPM	1.0	5.2	1.0	5.2
FORWARD EFFICIENCY @ END, GPM/SQ FT	1.6	8.7	1.6	8.7
TIME UNTIL HEAD LOSS ROSE TO 30 PSI, MINUTES	7-9	*	10	**
AVERAGE HEAD LOSS @ START, PSI	10-15	10-15	10	10
SPRITZ CYCLE, SEC/SEC	1/10	1/9	1/9	1.5/10

*Never reached 30 psi. Operation stable at 20 psi (12/3/68)
**Never reached 30 psi. Operation stable at 28 psi (3/6/69)

The above listed hydraulic test data represent the optimum runs obtained during the various categories of tests. Tests with polyethylene elements (d) were the most stable with flow being maintained absolutely constant on an indefinite basis following pretreatment settling of the raw sewage influent for 30 minutes without flocculants. While the operating head loss was slightly above that encountered with stainless steel elements, the overall improvement in performance and the substantial economies involved in plastic elements led to the selection of this material for the Phase II system.

(3) Phase I System Optimization

During the various tests listed in the Appendix, variations in settling time, spritz sequence, and backwash pressure were made as part of the system optimization process. Recalling that tests under category (d) resulted in a constant flow situation without need for a longer backwash cycle from time-to-time, it can be seen that this condition required backwash water during spritz alone amounting to 15% of forward flow. Both clear water and filtered effluent were used for backwashing without an appreciable change in performance. This amount of backwash water could have been reduced by allowing the filter elements to clog up gradually during forward flow to a point where a more frequent backwash cycle would be required. This periodic backwash procedure was programmed by the control system to last for three minutes during which time the canister was fully emptied and refilled with backwash water pressurized at 50 psi three successive times while the ultrasonic energy was applied continuously. This sequence restored clogged filter elements to a like-new condition in every case and was employed routinely at the end of each day's testing. Thereafter, the canisters were filled with fresh water to which liquid chlorine was added to inhibit clogging caused by organisms growing during shut-down periods. Total amount of water consumed during each complete backwash cycle was approximately 6 gallons.

An important objective of the Phase I program was to select the optimum pore size for the filter elements. Initial tests with stainless steel elements in the 50 and 100 micron pore size range revealed equal hydraulic performance for both. Smaller pored elements were rejected because of poor flow characteristics. Thus, the 50 micron pore size was used. Subsequent work with porous polyethylene permitted the use of 30 to 35 micron pore size elements, a standard value obtained from the manufacturer. Ten micron pore size elements were investigated but were not used, primarily since they were mechanically unstable in the early stages of the program, and, secondarily, because of their lower flow efficiency. Since the 35 micron elements performed adequately, they were selected for use in the Phase II system. It should be recognized that a final selection of filter pore size depends strongly on the interaction between actual influent contamination levels and

hydraulic variables involving the desired forward flow efficiency, the spritz sequence, the backwashing sequence and the backwash pressure. Filtration systems of this type are best operated under stable influent conditions, such as those encountered in treating ordinary domestic sewage. With widely varying contamination levels in the influent, the system operating parameters may have to be changed accordingly if premature clogging is to be avoided.

(4) Phase I Laboratory Analyses

Also included in the Appendix are measurements of BOD and suspended solids in the filtration system's influent and effluent. Using 35 micron elements and settled raw sewage, a BOD reduction of 39% and a reduction in suspended solids of 15% were obtained. With similar filter elements and an influent obtained from the effluent of a secondary treatment plant, a 50% reduction in BOD was obtained along with a 35% reduction in suspended solids. It was clear that the crude settling used with raw sewage in itself produced a significant reduction in suspended solids introduced thereafter to the filter, as evidenced by the formation of a settled sludge at the bottom of the sedimentation tank.

(5) Phase II System Guidelines

As a result of the data obtained during Phase I tests, the design of the Phase II canisters was enhanced somewhat by increasing the size of the filter elements to 12 inch length and 3 inch OD, an increase in surface area amounting to 0.8 sq ft as opposed to 0.6 sq ft for the smaller elements. The polyethylene filter elements finally selected were one-piece cylinders with a 3/16 inch wall thickness having plastic-welded end pieces and fittings. Previously evaluated polyethylene sleeves 1/16 inch diameter, which were slipped over open plastic support frames, were discarded because of weak structural strength. Otherwise, the Phase II system was designed to be similar in all respects to the Phase I system in terms of ultrasonic power, control sequencing and general appearance.

PHASE II - Design, Fabrication, and Operation of the Phase II Field Unit

A. Semi-Automatic Ultrasonic Filtration Unit (Fig.3a & 3b.)

The nominal 250,000 gpd filtration unit included the following:

20 stainless steel canisters, each fitted with influent port, effluent port, backwash port, drain, and air vent.

Canisters manifolded in 5 banks of four canisters each, each bank in turn connected to the system manifold through automatic and manual valves.

Each canister containing a microporous polyethylene filter element. The cylindrical elements are sealed at the bottom, and fitted at the top with a connection to the effluent and backwash manifold. Influent flow is into the canister body, through the filter element, and out the top fitting to the manifold.

An electrostrictive ultrasonic transducer, driven by a generator in the electrical control console, on the bottom plate of each canister. The transducer is activated during frequent, short backwash cycles ("spritz") one second out of each 10 or 20 seconds, and during a long-clean backwash 3 minutes out of every 15 minutes.

Dual pressure gauges: One of the inlet side of one canister in each bank; one on each system manifold line.

A system manifold fabricated from 3" iron pipe, to supply influent and backwash flows to each bank manifold, and to remove filtrate and "spritz" drain flows from each bank manifold.

An air compressor and air storage tank, supplying control air to solenoid valves for operation of the automatic flow control valves.

An influent pump of 200 gpm capacity, to supply pretreated sewage to the filters.

A backwash pump.

Flow meters in the drain and backwash lines on one filter bank.

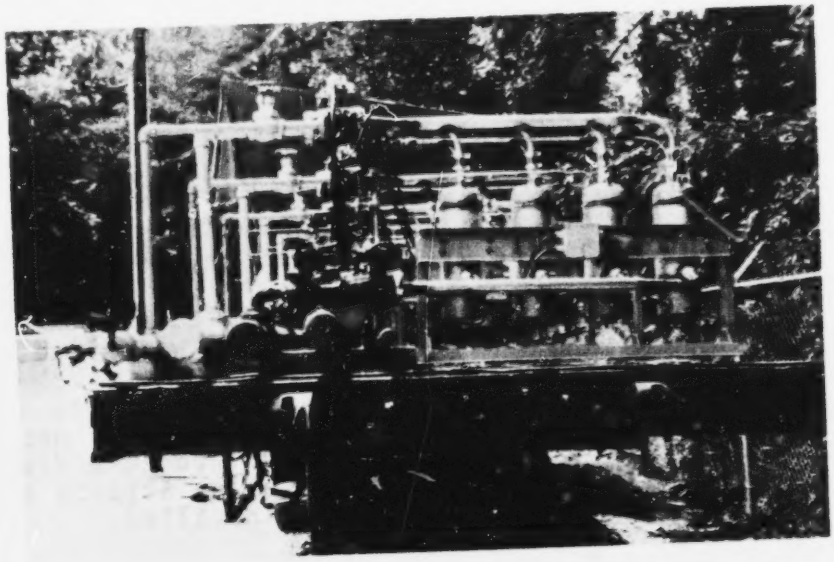


Fig. 3a - End View - Phase II Trailer

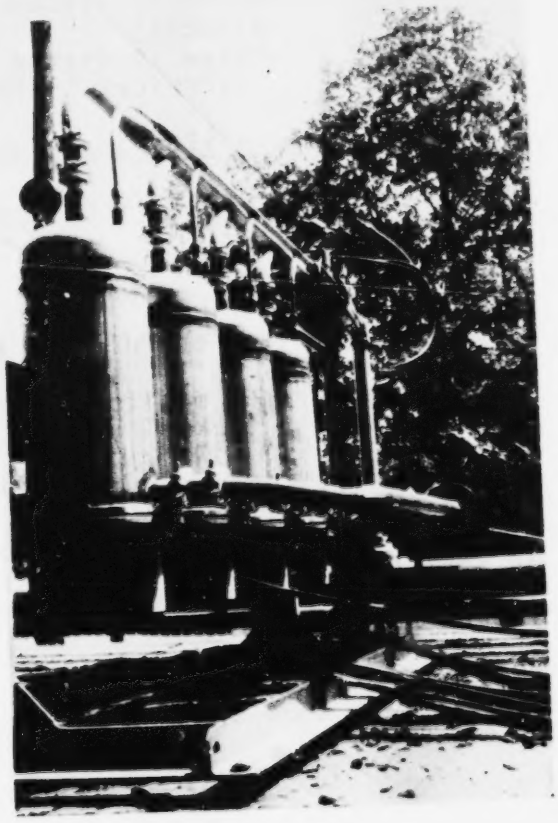


Fig. 3b - Typical Bank of 4 Filter Canisters

A power supply panel, to supply the control electrical power to the pumps, air compressor, and electronic control panel.

An electronic control panel, including two 700 watt 22 kHz ultrasonic generators, stepping switches, control circuits, timers, manual over-rides, and a lighted control panel array showing the operational status of each bank of filters at any moment.

A pump to inject hypochlorite disinfectant into system at time of shutdown, through the backwash line.

All the foregoing system components were assembled and mounted on a 38 foot flat bed trailer to provide mobility for testing at a sewage treatment plant and at a field test site. Figs. 4, 5, 6, and 7 illustrate the Atlanta test site and the major system components installed.

The following figures and drawings illustrate the design and fabrication of the trailer-mounted filtration unit.

Fig. 8	Basic Canister Design
Fig. 9	Phase II System in Assembly
Fig. 10	Phase II System Schematic of Plumbing
Fig. 11	Phase II System Schematic of Electrical Controls

Operating Instructions - Microfiltration Unit

1. Open all manual valves between system manifolds and each bank of canisters.

2. Turn on power supply.

3. Start air compressor, set control at 70-75 psi.

4. Open valves between system manifold and influent supply, backwash supply tanks.

5. Turn on power to electronic control panel.

6. Open all vents, using over-ride switches on electronic control panel.

7. Start influent pump.

8. Start backwash pump.

Fig. 4 - SEWER OUTFALL

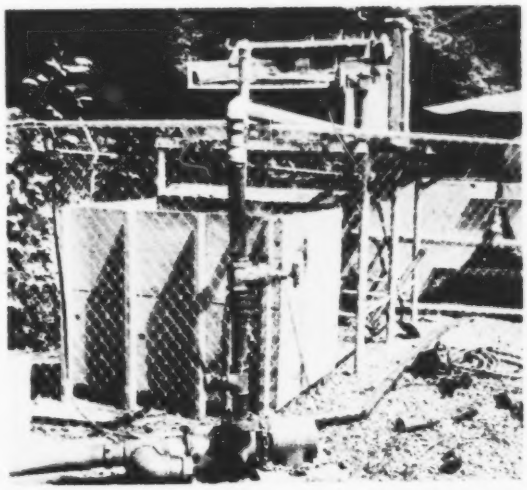


Fig. 5 - SHAKER SCREEN & TRASH BOX

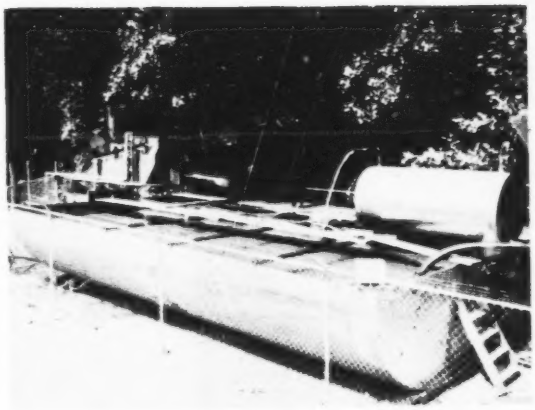


Fig. 6 - SETTLING TANKS

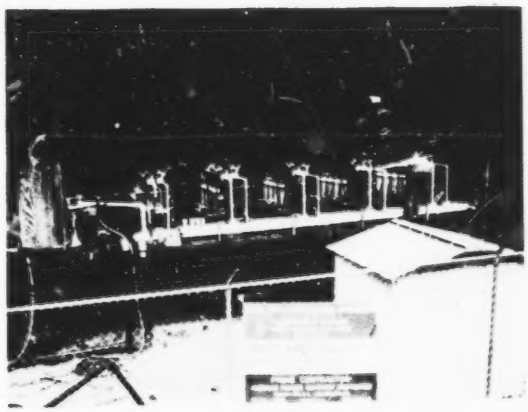


Fig. 7 - TRAILER SYSTEM

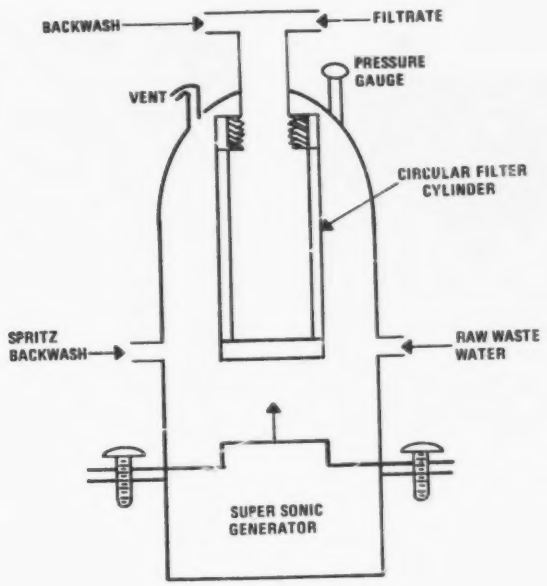


Fig. 8 - BASIC CANISTER DESIGN

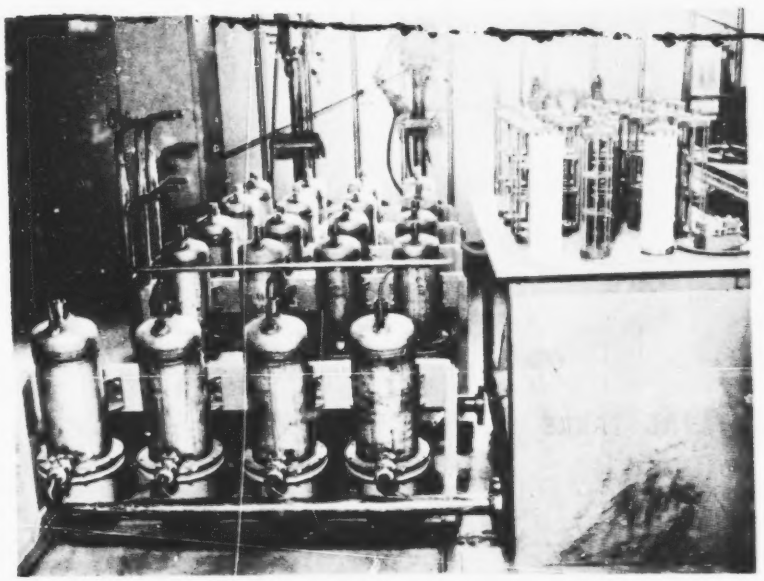
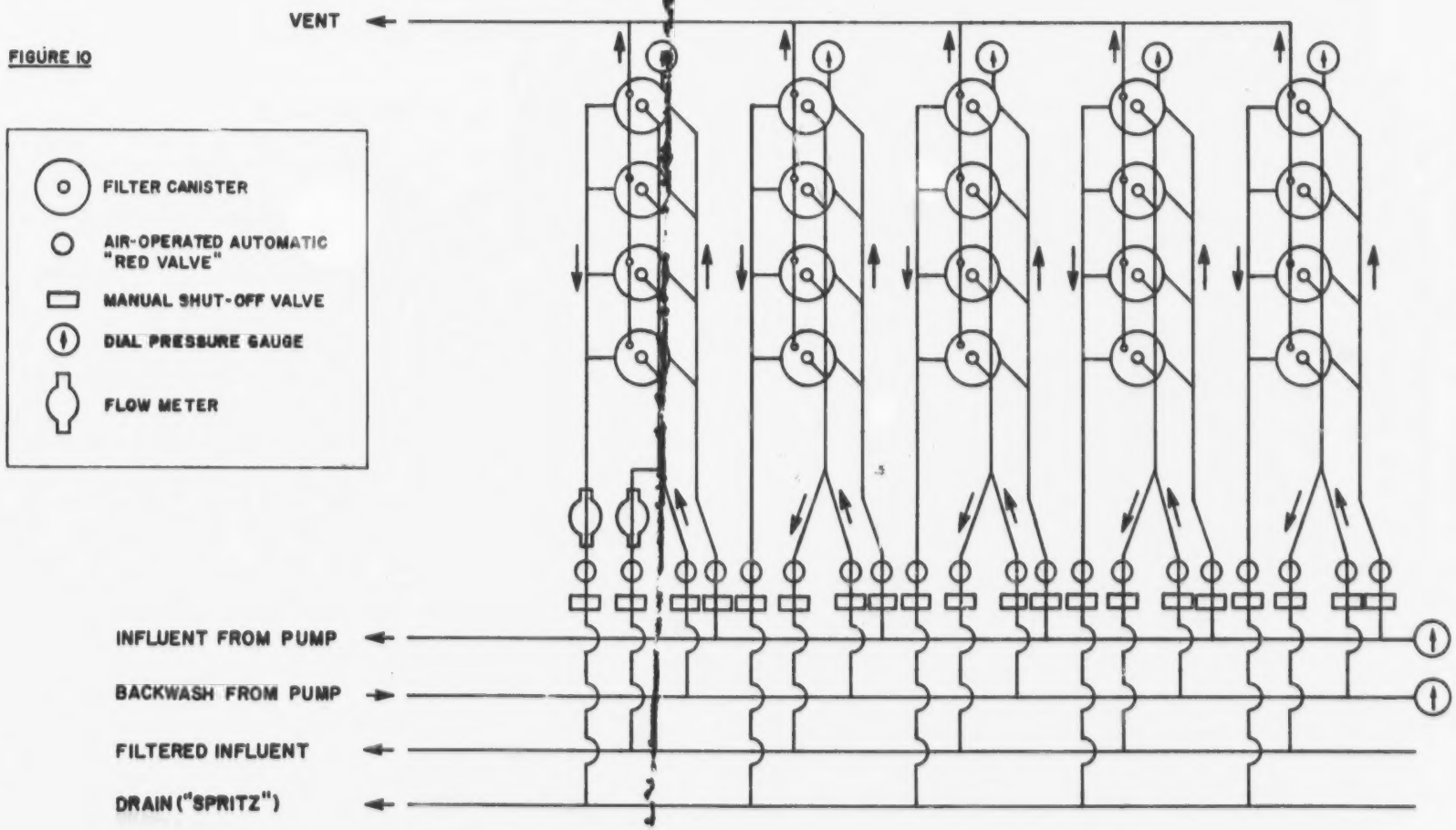
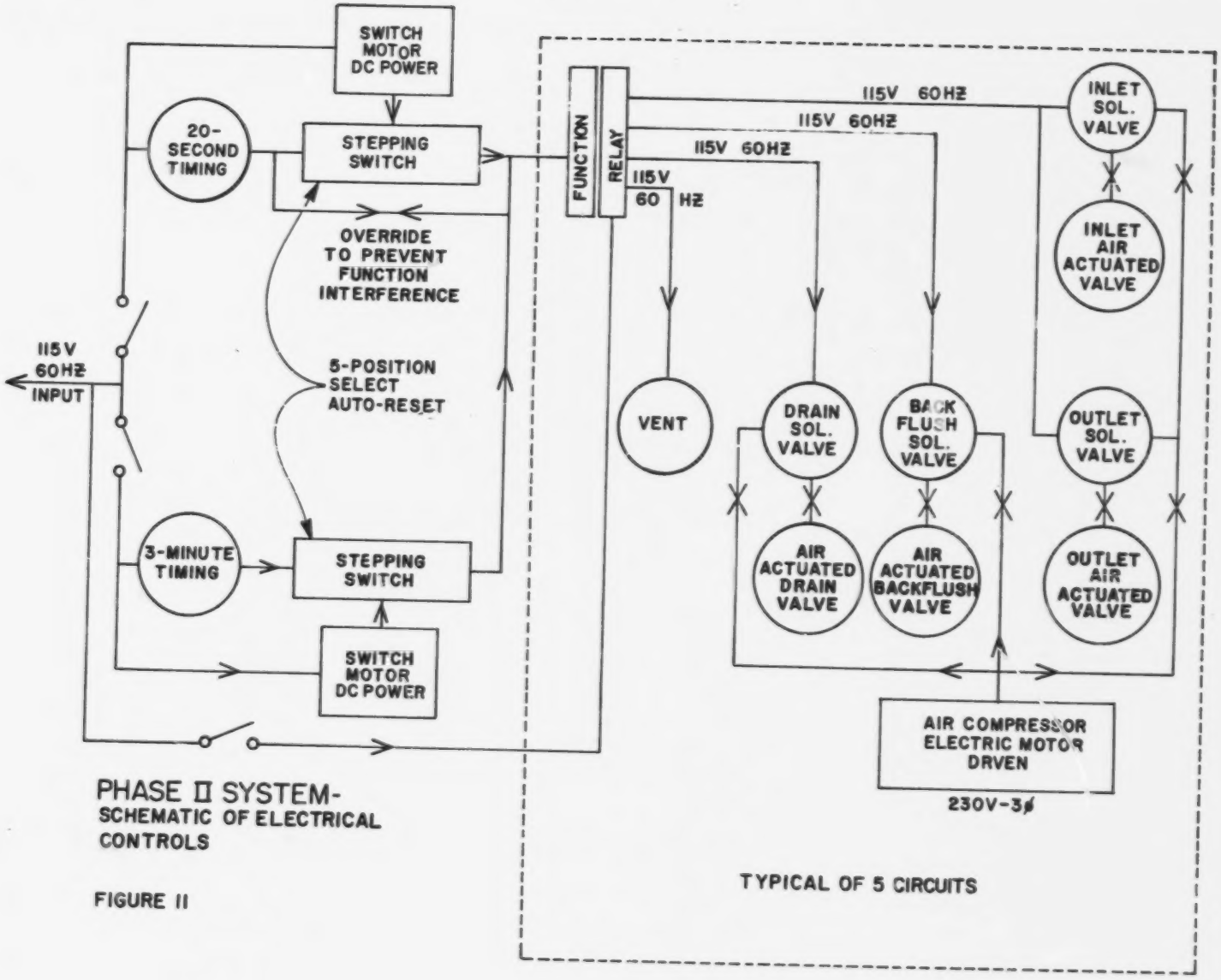


Fig. 9 - PHASE II SYSTEM IN ASSEMBLY

PHASE II SYSTEM - SCHEMATIC OF PLUMBING

FIGURE 10





PHASE II SYSTEM-
SCHEMATIC OF ELECTRICAL CONTROLS

FIGURE II

9. Start automatic control sequencing system (1 minute and 3 minute timers) on electronic control panel. Return vents to automatic control.

10. Using manual valves, adjust influent pressure to each bank of canisters to 25-35 psi.

11. Using manual valves, adjust backwash pressure to 50 psi.

12. Observe control panel light array to assure that all banks and valves are operating in proper sequence.

13. Observe pressure gauges and flow meters to assure that operation is normal and stable.

The system now should be in fully automatic operation. The operator will accordingly have ample time to operate and check on auxiliary equipment, take samples, maintain log data for operations.

Shut-Down Procedure

1. Turn off influent pump.

2. Turn off air compressor and air to solenoids. This will leave all automatic valves open. Shut all manual valves except backwash valves.

3. Turn off electronic controls at panel.

4. Backwash should now be flowing through all 20 canisters. Introduce two gallons of hypochlorite disinfectant solution into backwash stream. Continue flow until chlorine can be detected exiting from the drain line. (Disinfectant need not be introduced for short shut-downs).

5. Turn off backwash pump.

6. Shut backwash manual valves. Shut influent and back-wash valves between system and supply tanks.

7. Turn off power to electronic control panel.

8. Turn off power to electrical power supply panel.

B. Testing of Ultrasonic Microfiltration System at a Panama City, Florida, Sewage Treatment Plant

The 20-canister, 250,000 gpd trailer-mounted filtration system was temporarily installed at the Millville Treatment Plant, Panama City, Florida. Key features of the installation were:

Influent to system was primary treatment effluent, without further pretreatment.

Backwash was city water pumped at 80-90 psi from a pool reservoir.

"Spritz" cycle was 1.7 seconds on, 9 seconds off.

Before introducing sewage into the system, operation was checked using an influent of city water directly from a main. All aspects of the system performed according to design ... automatic cycling, "spritz" timing, long clean periods with backwash. Total forward flow through the system exceeded design capacity, averaging more than 15 gpm per canister, an efficiency equal to 19 gpm/sq ft. The system was operated for 6 hours at a time for the greater part of a week.

Following this demonstration that the system was mechanically and electrically performing at or exceeding design goals, the system was operated with an influent of primary treatment effluent. The influent pump installed on the system was used. Again, forward flow was 15 gpm per canister, or 240 gpm for the 16 canisters operating at any given time. This corresponds to a daily flow rate of 345,600 gpd, well in excess of nominal design capacity of 250,000 gpd.

During these filtration tests using primary sewage from the Millville Plant, two sets of influent and filtrate samples were taken. Five day BOD analyses performed by Millville Plant personnel showed an average reduction of BOD across the filter system of 51%, from about 90 ppm to 45 ppm. All canisters were fitted with 35 micron porous polyethylene elements.

C. Field Site Installation and Phase II Test Program

It was decided to site the Phase II twenty canister system at an appropriate pollution point in the Southeast, selected from a half-dozen potential locations mentioned during discussions between FWQA and the Contractor. These included Augusta,Savannah, Columbus and Atlanta, Georgia, plus two others too inconvenient to reach in the ordinary course of the program. The selection of the appropriate site was governed in the main by the availability of a nearby qualified laboratory testing firm, since it was not felt proper to impose upon the facilities used by the various municipalities for their own analyses. A further consideration was to locate an independent organization to monitor the Phase II test program and provide an impartial analysis of results.

These various considerations narrowed the selection of a site to Atlanta and the retention of the Georgia Institute of Technology's Research Institute to provide both program monitoring and necessary analytical laboratory services. Accordingly, the Contractor executed a subcontract with the Georgia Tech Research Institute and obtained as the principal investigator the services of Dr. Robert S. Ingols, an authority in waste water treatment and analysis. In conjunction with Dr. Ingols and local FWQA representatives, the Contractor visited with the Georgia Water Resources Council and cognizant engineers of the City of Atlanta and agreed upon a Phase II test site at the McDaniel Street outfall not far from Five Points, the heart of the City. At this outfall, dry weather sewage normally diverted to the South River Treatment Plant emerges from an antiquated sewer main built in the 1880's. During storm conditions, the mixture of sewage and storm water overflows a weir and passes down into a creek behind a number of homes on its way to a river system near Savannah. Such overflows occur routinely throughout years of normal rainfall, but during the extraordinarily dry summer just ended, overflows occurred only rarely.

The location of the McDaniel Street outfall is on a City owned cul-de-sac some 1,000 ft from the nearest home and power and water. The Contractor was permitted to site his various equipments on a gravel-filled area adjacent to the manhole diverting dry weather flow to the treatment plant.

The trailer-mounted ultrasonic microfiltration unit was set in place at the site. Required electrical service was provided, a limited fresh water supply was obtained through a garden hose from a nearby Boy Scout building, and lighting, security fencing, and telephone service were installed.

Auxiliary equipment was procured and installed as follows:

A WEMCO torque-flow pump to lift sewage from a city-owned manhole.

A booster pump to permit pumping raw sewage at the required rates against the high head required by the terrain.

A boom and hoist to permit removal of the WEMCO pump as periodically required to provide access to the manhole for city sewer maintenance employees.

A Link-Belt 20-mesh shaker screen to remove gross solids from the raw sewage, and appropriate hoses, rakes, and solids collection box.

Two hemi-cylindrical settling tanks, connected in series to provide up to two hours' settling time prior to filtration. Nominal capacity, 10,000 gallons.

A 300 gallon fresh water supply tank for backwash, sewage dilution, etc.

Piping and hose connections to bring sewage to the field unit and to return filtrate and drain discharges to the sewer.

Weir boxes to measure flows of the filtrate and drain discharges.

At a later date, a 3-inch water line was installed from the nearest city main over 600 feet away to provide fresh water volumes needed for backwashing and preparing simulated combined sewer overflows.

The Georgia Tech Research Institute, as subcontractor, installed analytical equipment and monitoring instruments, including a Honeywell No. W-10 river monitor, pH meter, turbidimeter, conductivity meter, and a non-recording rain gauge.

A protective enclosure was built over the control panels on the trailer; steps, catwalks, and guard rails were added as required for safe operations; and a storage shed for tools and materials was erected.

As noted earlier, the site was selected because of a history of frequent combined sewer overflows during heavy rainfall periods. However, during the time available for operating the field unit, rainfall was very infrequent and of short duration, so that no real test with actual combined sewage was possible. Attempts to achieve meaningful results with combined sewage during two very short rainfall periods were unsuccessful.

Discussions with the Project Officer at this point led to a decision to modify the field unit to permit operation with dry weather sewage, diluted to simulate combined sewer overflows. A first approach was to dilute screened dry weather sewage with filtered effluent. This approach was unsuccessful. Detailed analyses of extended runs made with this configuration were provided by the Georgia Tech Research Institute. During these runs, the filtration unit appeared to be operating normally, but recirculation of the filtrate to dilute the raw sewage resulted in a rapid build-up of unfilterable suspended solids within the system. As a result, reductions of BOD, COD, and bacteria count across the filter were low -- in the range of 5 to 25%. The data cannot be considered significant as a measure of filter performance, however, because of the recirculation system used. During the course of these runs, turbidity of the filtrate actually increased, due to a build up in unfilterable suspended solids.

The subcontractor concluded that recirculation of filtrate as diluent would preclude any meaningful results relative to filter efficacy. Accordingly, and in view of a continuing dry summer and lack of actual combined sewer overflow availability, it was decided to use fresh water for both diluent and backwash. To enable such operation, an additional fresh water supply was necessary, and the contractor installed a 3-inch line from the nearest city main more than 600 feet away.

Several runs were made with raw, dry weather sewage diluted with twice its volume of fresh water. Fresh water was also used for backwash. Mechanically, the field unit was operating in accordance with design; and, in fact, throughout the field test period, the electronic control system, the ultrasonic cleaning devices, and other components of the trailer-mounted filter system performed reliably. An exception to this was frequent rupture of rubber sleeves on the air-operated automatic "Red Valves." Replacement of those valves to provide more acceptable reliability under operating conditions is recommended for future test programs.

Subcontractor analyses of runs made with fresh water dilution to simulate combined sewage were at first extremely encouraging; BOD was reduced 66 to 80%, suspended solids were reduced to as low as 2 ppm with an influent containing 72 ppm!

It was, of course, suspected that such data resulted from a malfunction of the overall system, and, accordingly, these data were rejected and not reported upon herein. The Contractor and Subcontractor hypothesized that somehow the "filtrate" quality was so excellent as a result of dilution rather than of filtration removal of contaminants, that further experiments were devised to determine exactly what was happening. Conductivity of influent, filtrate, and drain streams was measured, and flow rates of each were monitored to provide a reasonable materials balance.

The results of these tests proved our hypothesis to be correct. The "filtrate" stream was in fact 50 to 80% fresh water, and the drain ("spritz") effluent was 65 to 85% unfiltered influent. The reason for this anomolous performance was sought and identified. Fine rust particles had become lodged permanently in the porous polyethylene filter bodies, causing a 75 to 90% reduction in filtration efficiency. Automatic operation of the filter system was thus effecting a flow-switching process, in which the major portion of influent was by-passing the filters and exiting through the drain line. Likewise, the major portion of fresh-water backwash was by-passing and exiting through the filtrate line.

Sources of filter-clogging rust particles were identified. The pretreatment settling tanks and the system manifold piping were the major sources, with substantial corrosion caused by the high pH and other attributes of the excessively variable industrial-domestic dry weather sewage at the field site. A second source of rust particles was the city fresh water supply itself. Filter discoloration from rust was noticeable after passage of only 15 gallons of city water through a new element. The plugging rust was not removed by the normal ultrasonic cleaning action of the system, and in fact would be removed only by dissolution in concentrated hydrochloric or nitric acid.

Particle size distribution analyses of screened settled sewage at the McDaniel Street field site, which were made by Georgia Tech, gave further insight into why the particular filter did not achieve meaningful improvement in waste water quality. Following pretreatment (settling), 95% of the suspended solids in the sewage were shown by

laboratory analyses to be unicellular bacteria of less than 5 microns diameter that passed through the 35 micron filter pores unimpeded. To capture such small particles (in the absence of the otherwise overpowering rust) would have required the use of 1 micron stainless steel elements of far higher cost and substantially lessened flow capacity.

The clear conclusion from these studies is that the Contractor's ultrasonic microfiltration system is not yet suitable for effective treatment of combined sewer overflows at the Atlanta site until more is known about pretreatment and rust-handling requirements. Without pretreatment, the sewage is so variable and at times so strong that filter plugging precludes reliable operation. With conventional time-dependent gravity settling pretreatment, the remaining suspended solids analyzed in Atlanta were primarily unicellular bacteria of less than 5 microns diameter that are not subject to effective filtration at the desired efficiency of 10-15 gpm/sq ft. These conclusions reinforce the Contractor's recommendation that low cost, instantaneous pretreatment processes, such as the proposed vortex separators, be ultilized for such combined sewer overflow treatment problems followed, if necessary, by an ultrasonic filtration system.

Subsequent to the conclusion of this program and during the period when the final report was under preparation, a reason for the rapid, irreversible plugging of the polyethylene filter elements by rust became more apparent. An analysis of various filtration systems of possible value in treating fresh water, which was conducted by personnel of the United States Public Health Service, revealed an extreme tendency of polyethylene to absorb rust by the polyelectrolyte effect. Since one of the main causes of fresh water contamination is rust, it has been concluded that stainless steel elements are to be preferred over polyethylene in applications where rust is present.

This finding indicates that polyethylene filters have value in treating rust-free domestic sewage but that stainless steel must be substituted in applications where rust can be encountered. The question remaining unanswered at this time is whether the premature clogging of the polyethylene filter elements in Atlanta could have been obviated by substitution of stainless steel elements and, if so, how effective would the filtration system have been treating combined sewage when compared to its proven ability to filter raw settled domestic sewage at its full design capabilities.

D. Pretreatment Considerations

One of the main factors determining the utility of an ultrasonic microfiltration system, or any comparable filtration process, is the level of influent contaminents. The results of the Phase I and Phase II tests have indicated an approximate upper limit of 100 mg/l for both BOD and suspended solids in the influent above which performance of the filtration system suffers in terms of reduced flow and added backwash requirements. Below these levels, filtration of raw settled sewage and effluent from primary treatments was accomplished most economically at filtration efficiencies approaching 19 gpm/sq ft with reasonable amounts of backwashing water in the order of 15% of the forward flow, or less. This waste water/fresh water ratio could possibly be raised substantially by shortening the spritz duration or by sacrificing the filtration efficiency.

With these parameters in mind, the need for pretreatment of highly contaminated influents becomes mandatory, especially when the levels of contaminents can vary widely during operating conditions. It is also clear that conventional time-dependent sedimentation processes used for pretreatment obviates the main advantage of the ultrasonic filtration system, namely its ability to treat waste water continuously on an "instantaneous" basis. The program has also indicated that sedimentation treatment of storm water is not only inefficient in terms of the space required for holding tanks; the actual sedimentation time must be varied to accommodate an influent that changes its consistency almost continuously.

During April of 1968 when the Santa Barbara oil incident occurred, the Contractor, at its own expense, developed a novel device for instantaneously removing oil from sea water using a highly simplified, gravity-assisted vortex separation technique and has been successful in obtaining FWQA support to build a pilot system rated at 1 MGD. This new system is unique in being able to remove floating or floatable material with a minimum of pumping power, space and cost.

The Contractor's so-called "VORSEP" oil-water separator has been modified recently by the addition of compressed air to act as an instantaneous air flotation unit which appears to have great promise in treating storm water and a host of other waste waters, including raw sewage.

In early December of 1969, after concluding the contract being reported upon, tests of a Contractor-owned prototype VORSEP with air flotation added were made under relatively crude operating conditions at Hyperion. These tests demonstrated a 21% reduction in BOD and a 50% reduction in the volume of settleable solids passed through this device.

During February, 1970, the performance of this prototype VORSEP was greatly enhanced by the use of an improved pump that permitted the raw sewage influent to be more properly aerated. The test results obtained during the third and most efficient set of runs in which laboratory data were obtained are as follows:

	FLOW	BOD	SOLIDS BY VOLUME
INFLUENT	10 gpm	214	3.0 ml/l
EFFLUENT	7 gpm (Reduction = 45%)	115	0.6 ml/l (Reduction = 80%)
CONCENTRATE	3gpm	227	11.0 ml/l

The above noted data were obtained during a test run using a nominally rated system of 50 gpm. The lesser flow of 10 gpm was the maximum obtainable with limited pumping and power facilities available at the time. It is known, however, from previous tests of the same VORSEP in the oil-water separation mode of operation, that at 50 gpm flow, the concentrate flow remains constant at the 3 gpm figure mentioned, or less. Thus, by obtaining the full 50 gpm flow of raw sewage influent, the ratio of influent to concentrate will approximate 17, instead of 3.3.

Recently concluded analyses and tests now indicate that a proposed VORSEP incorporating both means for instantaneously removing gross matter, such as grit and sand, from one exit port and floating materials, including grease, oil and particles of aerated sewage, through a second, centrally-located "vortex tube" exit port is entirely feasible in capacities up to 1 MGD or more. The diameter of a 1 MGD unit would be under 10 feet and the height under 15 feet. Aside from the use of a single low horsepower recirculation pump and an insignificant amount of compressed air, the unit would have no other moving parts except for a float control system. The cost of power is estimated

at 2¢/1,000 gallons, while the total 20-year amortized cost of a 1 MGD unit plus operating power is estimated to be 3¢ per 1,000 gallons, or less. In its optimized form, the VORSEP with flotation appears capable of removing up to 75% of the suspended solids in combined sewage of virtually any concentration, a performance figure surpassing that ordinarily obtained in today's time-dependent primary sedimentation processes.

Figs. 12 and 13 illustrate the general design features and appearance of typical VORSEP systems.

Should such a system in practice achieve its 75% SS removal goal, it could precede the ultrasonic filtration system in applications such as that encountered in Atlanta. Even greater removal possibly may be achieved with the VORSEP in conjunction with flocculants deliberately introduced in the influent line.

It is clear that a pressing need exists for some type of instantaneous pretreatment system and that a device, such as the VORSEP may provide measureable treatment at low cost and revolutionize the entire field of waste water treatment.

Without such a device, filtration systems are best used where some conventional type of pretreatment system is available to reduce the levels of contaminents to below 100 mg/l for both BOD and suspended solids or where the influent itself is relatively lightly loaded and consistent in composition.

E. Economic Evaluation of Combined Sewage Treatment Systems.

1. VORSEP PRETREATMENT ALONE, 25 MGD CAPACITY

(a) ESTIMATED COST

PLUS INTEREST AMORTIZED OVER 20 YEARS	$ 750,000
	750,000
TOTAL INVESTMENT IN HARDWARE	$1,500,000
TOTAL INVESTMENT, PER DAY	$ 205

(b) POWER COST (BASED ON 100% RECIRCULATION PUMPING, GRAVITY INFLUENT & 1,600 KW LOAD INTERMITTENTLY)

SERVICE CHARGE, PER DAY	$ 27
ENERGY CHARGE, PER DAY	$ 628
DEMAND CHARGE DURING SHUTDOWN (70% of ENERGY CHARGE)	$ 440

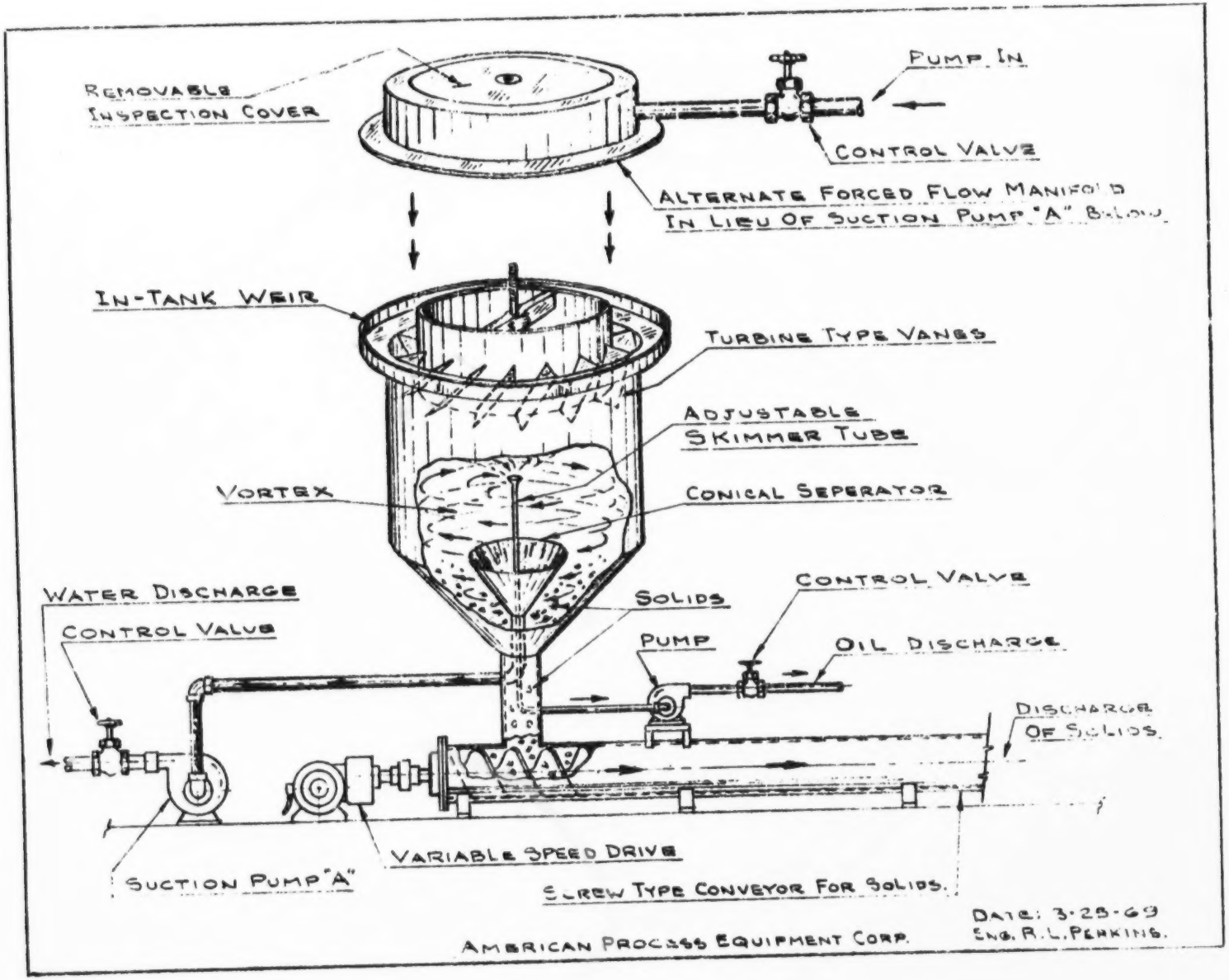


Fig. 12 - BASIC VORSEP SYSTEM

Fig. 13 - 50 GPM VORSEP IN OPERATION

	TOTAL POWER COST, PER DAY (AVERAGED)	$	561
	POWER COST, PER 1,000 GALLONS	$	0.02
(c)	ESTIMATED COST PER POUND OF BOD REMOVED ASSUMING 200 ppm BOD IN INFLUENT & 50% REMOVAL (2,500 LBS BOD FOR $766)	$	0.32
(d)	ESTIMATED COST PER POUND OF SS REMOVED ASSUMING 200 ppm SS IN INFLUENT & 50% REMOVAL	$	0.32
(e)	TOTAL ESTIMATED COST PER 1,000 GALLONS	$	0.03

ADD 10% TO EACH DAILY COST FIGURE FOR PERSONNEL AND SPARE PARTS.

2. ULTRASONIC MICROFILTRATION, 25 MGD CAPACITY

(a)	ESTIMATED COST LESS VORSEP PRETREATMENT	$2,600,000	
	PLUS INTEREST AMORTIZED OVER 20 YEARS	$2,600,000	
	TOTAL INVESTMENT IN HARDWARE	$5,200,000	
	TOTAL INVESTMENT, PER DAY	$	712
(b)	POWER COST (BASED ON PUMPED INFLUENT & 3,500 KW LOAD INTERMITTENTLY) SERVICE CHARGE, PER DAY	$	112
	ENERGY CHARGE, PER DAY	$	1,160
	DEMAND CHARGE DURING SHUTDOWN, (70% of ENERGY CHARGE)	$	812
	TOTAL POWER COST, PER DAY (AVERAGED)	$	1,050
	POWER COST, PER 1,000 GALLONS	$	0.04
(c)	ESTIMATED COST PER POUND OF BOD REMOVED ASSUMING 100 ppm BOD IN INFLUENT & 50% REMOVAL (1,250 LBS BOD FOR $1,760)	$	1.40

(d)	ESTIMATED COST PER POUND OF SS REMOVED ASSUMING 100 ppm SS IN INFLUENT & 50% REMOVAL	$	1.40
(e)	TOTAL ESTIMATED COST PER 1,000 GALLONS USING FILTERED EFFLUENT FOR BACKWASHING	$	0.07
(f)	TOTAL ESTIMATED COST PER 1,000 GALLONS USING FRESH WATER BACKWASH @ 10¢/1,000 GALLONS	$	0.08

ADD 10% TO EACH DAILY COST FIGURE FOR PERSONNEL AND SPARE PARTS.

The two previous cost analyses indicate that a system for treating combined sewage in two steps, first through the VORSEP for pretreatment and thereafter through the ultrasonic filtration system, can be accomplished for a total of $0.12 per 1,000 gallons in a 25 MGD system, including costs for personnel and maintenance. Power rates quoted are based on those of the Department of Water and Power, of the City of Los Angeles, which are among the lowest in the United States. In other localities, the additional cost of power up to 100% above the Los Angeles rates should be taken into consideration. These additional charges for power could roughly double the cost of removing one pound of BOD and suspended solids in each system. The cost for treating 1,000 gallons would rise more in the case of the VORSEP, wherein the cost of power per day amounts to 75% of the total daily cost. For the ultrasonic filtration system, power represents some 60% of the daily cost.

Some mention should be made of demand charges, since a combined sewage treatment system might well be used only intermittently. During shutdown periods, the cost of power is 70% of that used in operation, whether the system is used or not. Should power be available without this demand charge, the operating costs drop significantly for both systems by as much as 50%.

In these estimates, both systems have been analyzed based upon a 50% removal of BOD and SS each, with the influent to the VORSEP being estimated as having 200 ppm of both BOD and suspended solids. Since the VORSEP can accommodate far greater loads, the cost of removing these contaminents can

drop directly with the additional level of contamination as no extra power or equipment is required.* On the other hand, the ultrasonic filter cannot at this moment perform above the influent loadings for BOD and SS of 100 ppm and, thus, the removal costs are as stated.

Consideration should also be given to the space required by this 25 MGD treatment plant. Twenty-five 1 MGD VORSEPS have been selected for this application, each approximately 12 feet in diameter maximum. Thus, the ground area consumed by 25 units would be roughly approximate 10,000 square feet. The ultrasonic filtration system would occupy about 20,000 square feet in addition to make the total 30,000 square feet. A conventional time-dependent primary-secondary treatment plant would easily require ten times this space at a time when real estate is more expensive than ever. The instantaneous treatment capability greatly reduces space and makes possible the installation of fully-enclosed equipment that cannot be of an objectionable nature to nearby homes and buildings.

Lastly, the cost analyses have omitted consideration of sludge treatment, since the requirements for sludge disposal vary widely. For treating combined sewage during infrequent overflows, sludge can be stored in holding tanks for delivery to nearby waste treatment plants after surge conditions have passed. In any event, the requirements for sludge disposal using the VORSEP and the filter together could involve the disposal of 7,500 pounds of BOD and suspended solids per day which may be mixed with approximately 4 MGD of concentrate liquor. Of this 4 MGD, 2.5 MGD are exhausted by the filtration system. It is advantageous to include on the plant site a conventional sludge thickener or possibly several additional VORSEPS working in this function or a 4 million gallon surge holding basin for each day's continuous flow of sludge.

*Footnote No. 1 - With influent BOD and SS levels of 1,000 ppm each, the cost of removing one pound of contaminent will drop from $0.32 to $0.06.

SECTION 5

PATENTS

During the course of the program, there were no applications entered for patents covering any portion of the system. The basic patent covering the concept of ultrasonic filtration was applied for previous to the start of this contract effort and has recently been issued by the United States Patent Office. This patent is owned by Acoustica Associates, Inc., and is sub-licensed to the Contractor. This patent is identified as follows:

Serial No.	Inventor	Title
U.S. Patent No. 3,478,883	F. D. DeLuca, Jr.	Acoustic Filtration Apparatus

The VORSEP separation system described in this report has been developed by the Contractor under corporate funding and is presently the subject of a patent application to be filed with the United States Patent Office.

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SECTION 6

ACKNOWLEDGEMENTS

The Contractor is indebted to the Cities of Los Angeles, California; Panama City, Florida; and Atlanta, Georgia, for making available at various stages of the program test facilities in their respective cities. Personnel at the Hyperion Treatment Works, of the City of Los Angeles, under the direction of Mr. Alfred Leipzig, Chief Engineer, and Mr. William Garber, Assistant Chief Engineer, and the Millville Treatment Plant of the City of Panama City, were most cooperative in making available at no cost various items of equipments and working space which facilitated testing of the Phase I and II systems respectively. The Hyperion facilities were made available under authority of the City Council by Mr. Norman B. Hume, Director of the Department of Public Works, of the City of Los Angeles.

Full cooperation of the City of Atlanta was obtained through the efforts of Messrs. Richard W. Respess, Deputy Director, and J. W. Cameron, Engineer of Sewers, of the Public Works Department.

Acknowledgement of the services furnished by the Georgia Tech Research Institute under the direction of Dr. F. Bellinger are in order. The Contractor's sub-contracted effort to Georgia Tech was under the direction of Dr. Robert S. Ingols, who expended considerable time and effort at the McDaniel Street Site, in Atlanta, analyzing the waste water present and evaluating the performance of the Contractor's microfiltration system. Considerable of the data and assumptions contained in this Report have been extracted from test data and reports furnished by Dr. Ingols and his staff. Mr. Edwin Lomasney, of the FWQA Regional Office in Atlanta, was also most helpful in guiding the Contractor's efforts in Georgia.

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SECTION 7

GLOSSARY OF TERMS AND ABBREVIATIONS

The following abbreviations are used in this report:

ABBREVIATION	DESCRIPTION
BOD	Biochemical Oxygen Demand
COD	Chemical Oxygen Demand
kHz	KiloHertz, frequency in thousands of cycles
kw	Kilowatt
SS	Suspended Solids

The following uncommon terms are used in this report:

TERM	DESCRIPTION
Spritz Cycle	The sequence in which forward flow through a filter element is interrupted momentarily during which interval the filter element is cleaned ultrasonically while immersed in filter influent and during which interval a small amount of the influent surrounding the outer surface of the element is discharged.
VORSEP	A trade name applied to a vortex separation system developed by the Contractor.

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SECTION 8

APPENDIX

PART I - Phase I Hydraulic Test Data: Hyperion

During the period from November 11, 1968, to November 25, 1968, seven days of testing were conducted to establish basic operating characteristics. All tests of the Phase I system during this time had similar operating parameters. They were as follows:

Equipment	Phase I Dual Tank System
Filter Element	100 micron Stainless Steel 10" long, 2-3/4" OD, 3/16" thick.
Influent Pumping	One 3/4 hp Jabsco Pump
Influent	Raw Sewage thru 20 mesh screen settled for 1/2 hour and diluted 10:1 with water
Spritz Timing	1 sec/10 sec

Average results of the above tests were as follows:

Average Starting Influent Pressure	10-15 psi
Average Time Until Head Loss = 30 psi	7- 9 min
Average Starting Flow	5.5 gpm
Average End Flow	1.0 gpm

(Influent pressure consists of piping losses plus filter element back pressure.)

System always clogged up after short running time.

12/3/68-

Phase I system modified to include a pressurized backwash during the normal spritz time. During the short spritz interval of approximately 1 second on to 9 seconds off, the filter element received a pressurized backwash plus an ultrasonic cleaning.

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The other operating parameters were as follows:

Filter Element	50 micron Stainless Steel 10" long, 2-3/4" OD, 3/16" thick
Influent Pumping	One 3/4 hp Jabsco Pump
Influent	Raw sewage thru 20 mesh screen settled for 1/2 hour
Spritz Timing and Pressure	1 sec/10 sec, 50 psi

The results of the above test were as follows:

Starting Influent Pressure	10-15 psi
Time until Head Loss = 30 psi	Never obtained as pressure only built up to 20 psi
Starting Flow	5.5 gpm
Ending Flow	5.2 gpm

Addition of power spritz deemed major improvement.

12/4/68-

Operating parameters were the same as on 12/3/68; similar results were obtained.

12/5/68-

Operating parameters same as on 12/3/68, system had dirty filter elements from previous run. After back-washing system with strong hypochlorite solution, flow results of 4 gpm and an inlet pressure of 21 psi were obtained. This test showed that the system could be recleaned after being severely contaminated.

12/7/68-

Operating parameters same as on 12/3/68. 20 mesh screen on influent hose ruptured thus allowing unscreened sewage as influent. System performance: Flow 4.2 gpm, influent pressure 17 psi. Use of unscreened sewage as influent did not detract from performance.

12/10/68-

Operating parameters same as 12/3/68, except spritz timing equal to 1.4 sec/10 sec. System performance: Flow 4.5 gpm, influent pressure 16 psi.

12/12/68-

Operating parameters same as 12/3/68, except timing variable. System performance: Filter element clogged, therefore system was backwashed with strong hypochlorite solution and solution was left to sit in tank.

12/13/68-

Operating parameters same as 12/3/68, except spritz time equal to 2 sec/10 sec. System performance: Filter elements still clogged therefore filters were pulled and cleaned in acid.

12/18/68-

Operating parameters same as 12/3/68, except influent was fresh water. This test run was made to check for cleaned filters. System performance indicated that filters had been cleaned. Flow 6.50 gpm, influent pressure at 10.00 psi Tank #1, 5.00 psi Tank #2.

12/19/68-

Operating parameters same as 12/13/68. System performance: Flow 5.4 gpm, influent pressure 17.00 psi. Use of unsettled sewage at end of test run indicated that influent should be settled before filtration is attempted.

12/23/68-

Operating parameters:

Filter element -	40 micron Teflon, 10: long, 2-3/4" OD, 1/16" thick
Influent Pumping	Two 3/4 hp Jabsco Pumps
Influent	Raw sewage thru 20 mesh screen settled for 1/2 hour
Spritz Timing and Pressure	Variable, 35 psi

System Performance: Flow 7.5 gpm, influent pressure 28 psi

Filter clogged up rapidly; increase in influent pressure due mainly to using two Jabsco pumps on the influent.

12/26/68-

Operating parameters same as 12/23/68, except for use of 30 micron polyethylene filter, 10" long, 3" ID, 1/16" thick, and spritz timing equal to 1.6 sec/10 sec. System performance: Flow 9.4 gpm, influent pressure 18 psi. Polyethylene filter superior in flow characteristics.

12/30/68-

Operating parameters: Tank #1, 30 micron polyethylene filter, Tank #2, 40 micron Teflon filter. System performance: Tank #1 flow 5 gpm, influent pressure approximately 33 psi, Tank #2 flow 6.5 gpm, influent pressure 27 psi. Polyethylene filter element appeared to be deteriorating in its filtering ability.

1/2/69- MORNING

Operating parameters:

Filter elements	Tank #1, 30 micron Kynar 10" long, 2-3/4" OD, 1/16" thick.
	Tank #2, 50 micron Stainless Steel 10" long, 2-3/4" OD, 3/16" thick
Influent Pumping	Two 3/4 hp Jabsco Pumps
Influent	Raw sewage thru 20 mesh screen then settled for 2-1/2 hours.
Spritz Timing and Pressure	1.6 sec/10 sec, 80 psi

System performance: Tank #1 end flow 5.4 gpm, end influent pressure 27 psi; Tank #2 end flow 6.50 gpm, end influent pressure 27 psi.

Kynar filter deteriorated rapidly in its flow capability.

1/2/69 - AFTERNOON

Operating parameters same as 1/2/69, Morning, except Tank #1 had 30 micron polyethylene filter 10" long 3" ID, 1/16" thick. System performance: Tank #1 flow 7.75 gpm, influent pressure 25 psi. Polyethylene filter again showed superior flow capabilities.

1/3/69 - MORNING

Operating parameters same 1/2/69, Afternoon. Only tank with polyethylene filter was tested. Influent was taken from non-operating detritor. System performance: Flow 7 gpm influent pressure 29 psi. Polyethylene filter continuously maintaining its high flow capabilities.

1/3/69 - AFTERNOON

Operating parameters same as 1/2/69, Afternoon. System performance: Tank #1 flow 7 gpm, influent pressure 28.25 psi, Tank #2 flow 7.6 gpm influent pressure 23 psi.

1/6/69 -

Operating parameters same as 1/2/69, Afternoon. System performance: Tank #1 flow 6 gpm, influent pressure 34 psi, Tank #2 flow 6.8 gpm, influent pressure 26 psi. Filter elements performed basically the same. Difference in micron rating (30 microns for polyethylene against 50 microns for Stainless Steel) still indicated polyethylene to be better filter.

2/5/69

Operating parameters:

Filter Element -	30 micron Polyethylene 10" long, 3" ID, 1/16" thick
Influent Pumps	Two 3/4 hp Jabsco Pumps
Influent	Plant secondary
Spritz Timing and Pressure	1.0 sec/10 sec, 100 psi

System performance: With spritz turned off, system tested for maximum flow capabilities. After 30 minutes pressure remained constant at 17 psi and flow rate was approximately 12.25 gpm. Thus an obtainable maximum flow rate was established of around 12 gpm.

2/12/69 -

Operating parameters same as 2/5/69, except influent was raw sewage thru 20 mesh screen and not settled. System performance: No relevant information obtained from this test as polyethylene filter element ruptured and therefore was not actually filtering.

2/13/69 -

Operating parameters:

Filter Element	35 micron polyethylene, 10" long 3" OD, 5/16" thick
Influent Pumping	Two 3/4 hp Jabsco Pumps
Influent	Raw sewage thru 20 mesh screen settled for 1/2 hour
Spritz Timing and Pressure	1.5 sec/10 sec, 100 psi

System performance: Test was ended due to backflush pump failure, no relevant results.

2/25/69 -

Operating parameters same as 2/13/69, except Tank #2 contains 30 micron polyethylene, 1/16" thick filter element mounted on plastic cage support mechanism. System performance: Tank #1, flow 4.5 gpm influent pressure 31 psi; Tank #2, flow 2.75 gpm, influent pressure 32 psi. Results of this test showed 5/16" polyethylene filter superior to 1/16" polyethylene.

3/4/69 -

Operating parameters same as 2/13/69, except influent was plant secondary. System performance: Flow approximately 8 gpm, influent pressure 21 psi. Good performance from 5/16" thick filter element.

3/5/69 -

Operating parameters same as 3/4/69. System performance: Flow 8.5 gpm, influent pressure 20 psi. Increase in flow rate from 3/4/69 due mainly to new rotor being put into one Jabsco pump.

3/6/69 -

Operating parameters same as 2/13/69, except influent settled for 2 hours. System performance: Flow 5.2 gpm influent pressure 28 psi. This test represents performance of the finalized Phase I system. Average flow of 5.2 gpm indicates filter efficiency of approximately 10 gpm per square foot of filter area.

PART II - Phase I Hydraulic Test Data: Hyperion

Laboratory tests for BOD and tests for Suspended Solids were made by Truesdail Laboratories, Inc., of Pasadena, California, and by the Millville Treatment Plant in Panama City, Florida, for BOD only.

Samples were kept refrigerated pending delivery to the laboratory late in the afternoon following the tests.

At Hyperion, as stated previously, BOD was reduced an average of 39% and the suspended solids were reduced an average of 15% on settled raw sewage screened through 20 mesh screens.

On secondary sewage run directly through the filter system without screening, average BOD reduction was approximately 50% and suspended solids were reduced by approximately 35% using the 35 micron polyethylene filter element.

In Panama City the system was tested using the effluent from the Millville Primary Treatment Tank, operating continuously at a high flow rate of approximately 15 gpm per canister, with results showing a 51% reduction in BOD.

BIBLIOGRAPHIC: The American Process Equipment Corporation Ultrasonic Filtration of Combined Sewer Overflows EPA/WQO

ABSTRACT: A 250,000 gpd compact ultrasonically cleaned microfiltration system was tested with simulated combined sewer overflows and primary treatment plant effluent. Twenty 35 micron porous polyethylene elements of 0.8 sq ft area each comprised the system.

Simulated settled combined sewer overflows at Atlanta, Georgia test site quickly clogged filters with high concentrations of rust in both influent and fresh backwash water. Thus, feasibility of treating combined sewer overflows was not demonstrated. Study indicates use of more costly porous stainless steel elements would obviate this problem.

Sufficient test data are available to predict performance in more suitable water pollution control applications. With influent BOD and suspended solids levels of 100 mg/l, or less, ultrasonic filtration using 35 micron plastic elements can reduce BOD and SS in raw settled sewage, or effluents from primary and secondary plants by 50%. A 25 MGD system requires less than 20,000 square feet, and cost for treating 1,000 gallons is $0.08, excluding pretreatment.

Contractor's novel flotation vortex separator reduced raw sewage BOD 45% and influent solids 80%. This "VORSEP" could continuously treat combined sewer overflows, and/or pretreat influent to the ultrasonic microfiltration system. A 25 MGD Vorsep treats 1,000 gallons for $0.03, and requires 10,000 sq ft of space.

This report is submitted in fulfillment of Contract 14-12-195 between the Environmental Protection Agency Water Quality Office and American Process Equipment Corporation.

ACCESSION NO:

KEY WORDS

Ultrasonic Filtration

Combined Sewer Overflows

Vortex Separator

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1 Accession Number

2 Subject Field & Group

SELECTED WATER RESOURCES ABSTRACTS
INPUT TRANSACTION FORM

5 Organization

AMERICAN PROCESS EQUIPMENT CORPORATION

6 Title

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Ultrasonic Filtration
Combined Sewer Overflows
Vortex Separator

27 Abstract

A 250,000 gpd ultrasonically cleaned microfiltration system was unsuccessfull in treating combined sewer overflows at an Atlanta, Georgia test site. High concentrations of rust clogged the porous polyethylene filter elements. It is anticipated that with stainless steel filter elements, influent BOD and Suspended Solids concentrations of 100 mg/l or less could be reduced by 50%. A novel flotation vortex separator is described, which could serve as a pretreatment device for the filter.

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